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(54) MULTI-STAGE COOLING SYSTEM

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F01P 3/00 (2006.01)

(52) **U.S. Cl.** **123/41.29**; 60/599; 123/41.08; 123/563

(58) **Field of Classification Search** 123/41.01, 123/41.02, 41.08, 41.11, 41.29, 41.58, 563, 123/41.31, 41.1; 60/599
See application file for complete search history.

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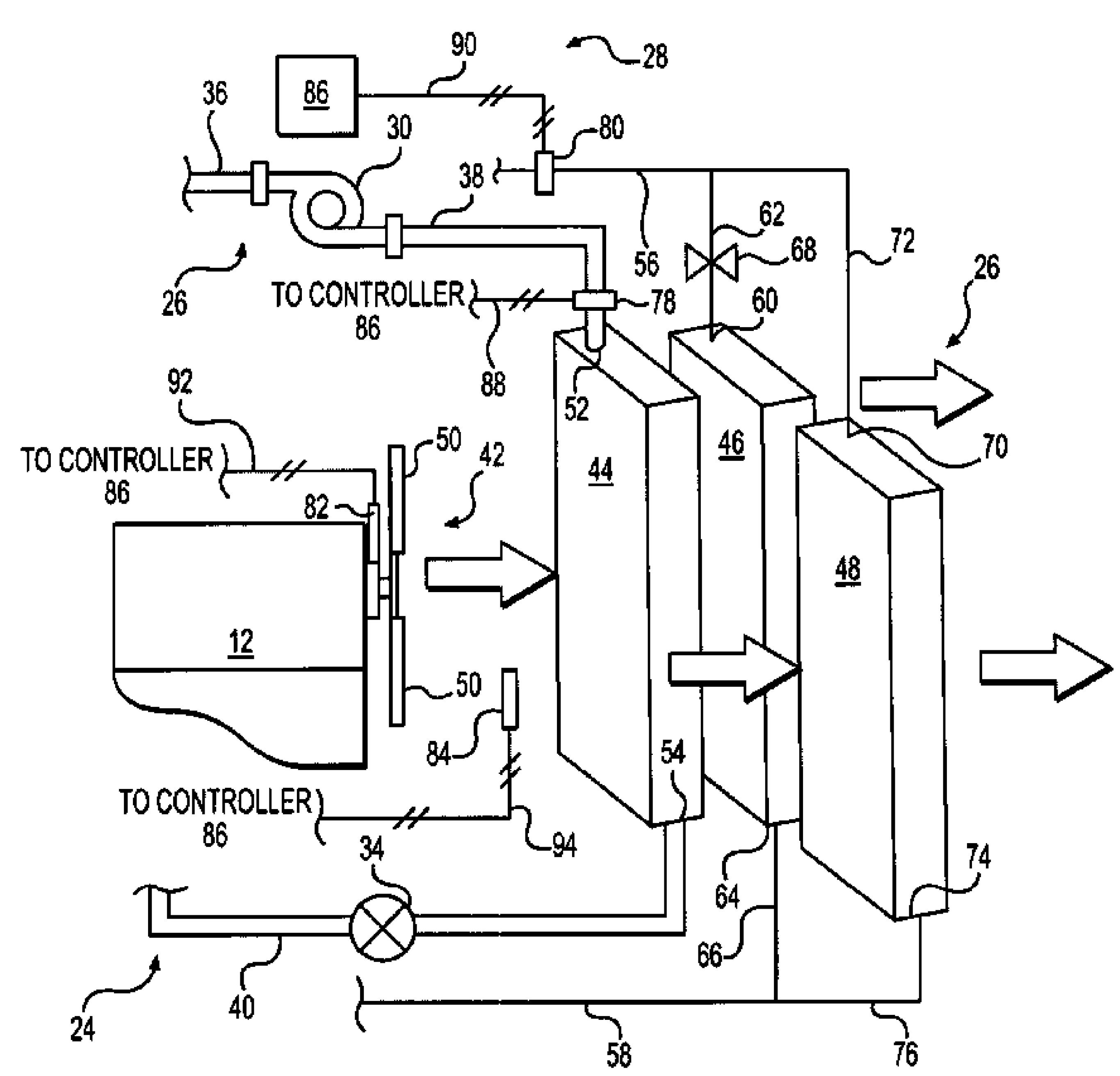
(57) **ABSTRACT**

A cooling system is provided having a first heat exchanger configured to remove heat from at least a portion of a first fluid and a second heat exchanger configured to remove heat from a portion of a second fluid. The second heat exchanger is located downstream of the first heat exchanger relative to the flow of air passing through the first heat exchanger so that a substantial portion of the air passing through the first heat exchanger also passes through the second heat exchanger. The cooling system also has a valve located to regulate the flow of the second fluid through the second heat exchanger. The cooling system further has a controller configured to actuate the valve to restrict the flow of the second fluid through the second heat exchanger when the first heat exchanger is removing heat from the first fluid.

20 Claims, 3 Drawing Sheets



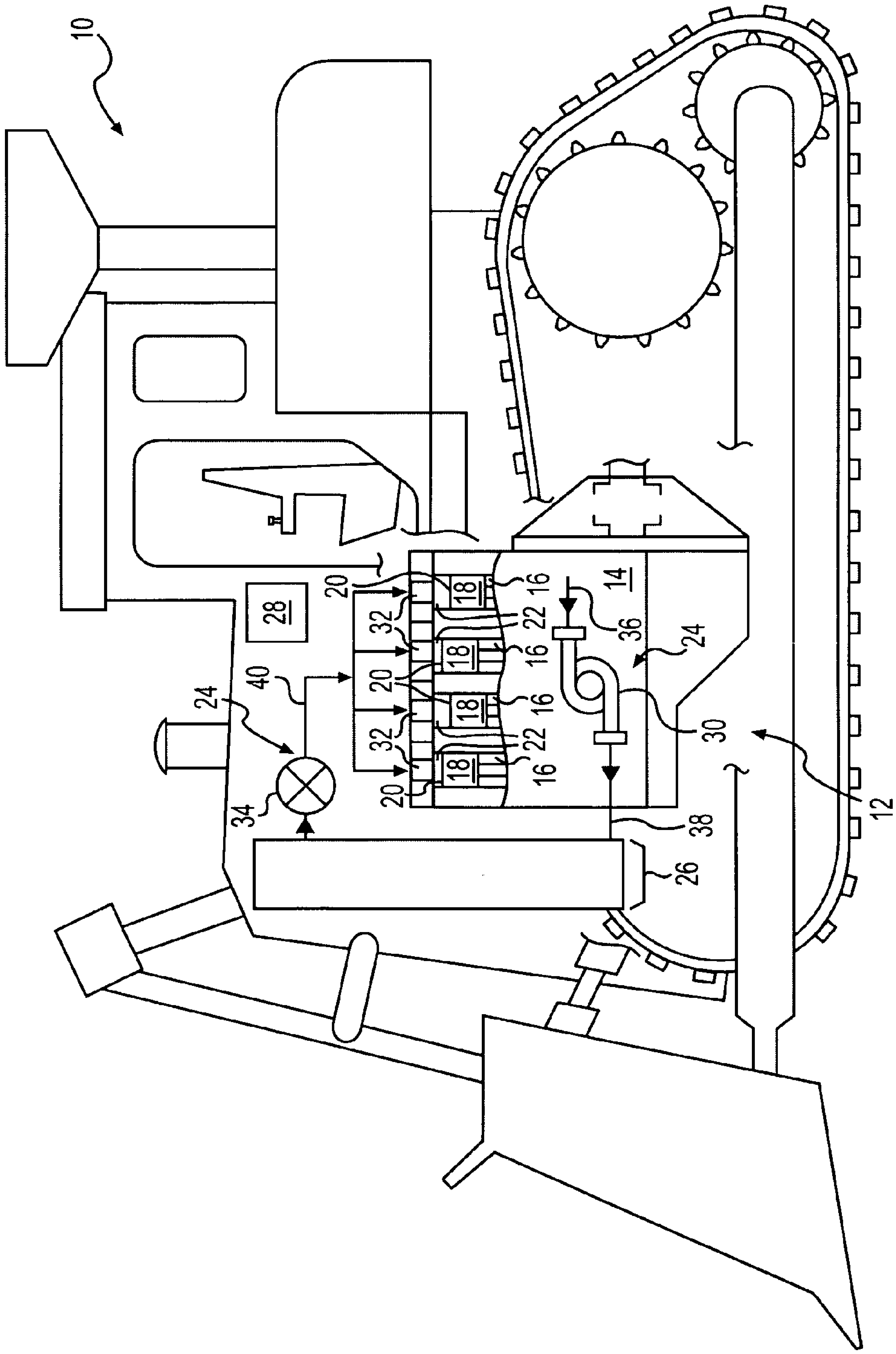


FIG. 1

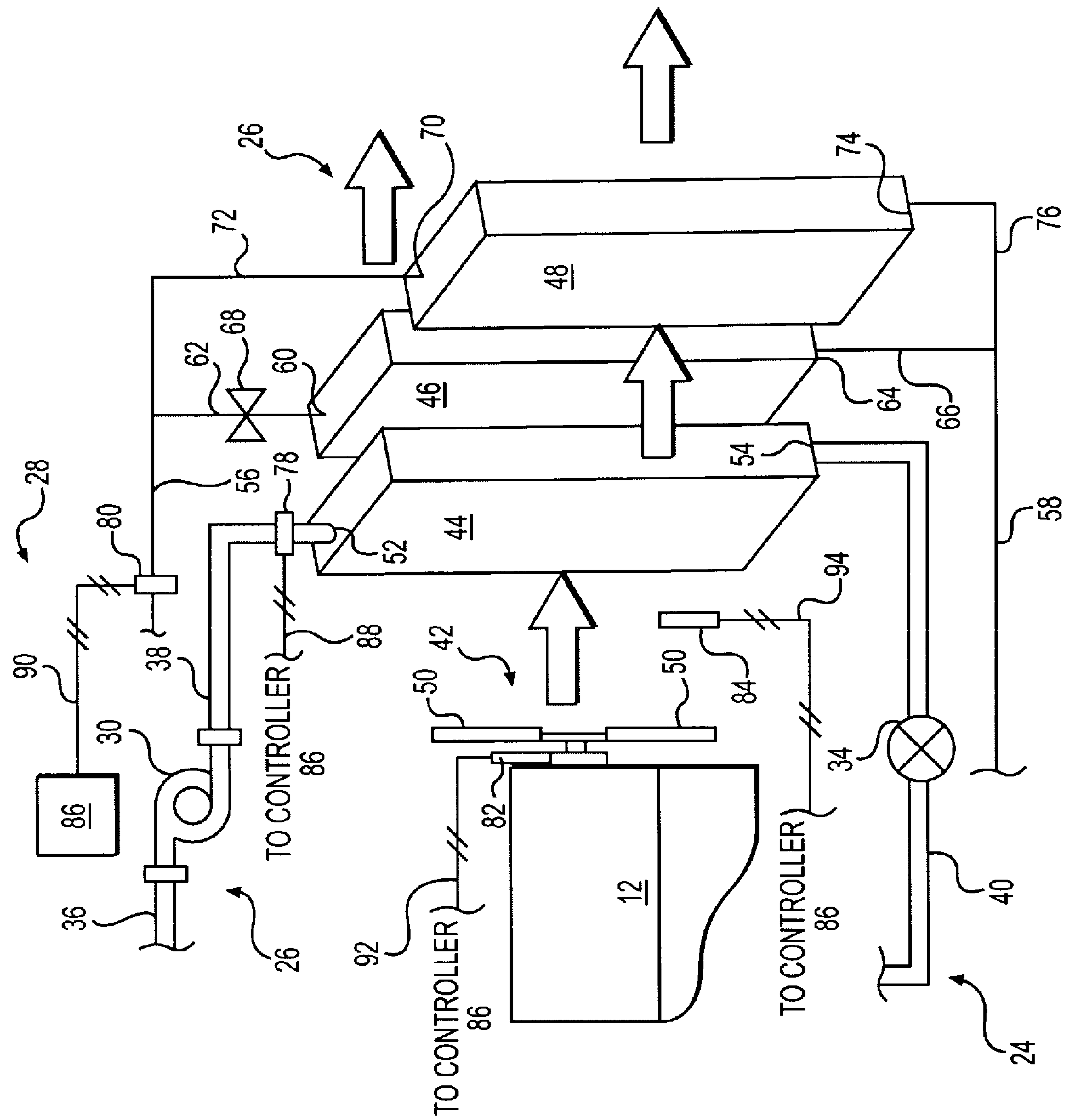

TO CONTROLLER 86
TO CONTROLLER 86
TO CONTROLLER 86
12
44
46
48
86

FIG. 2

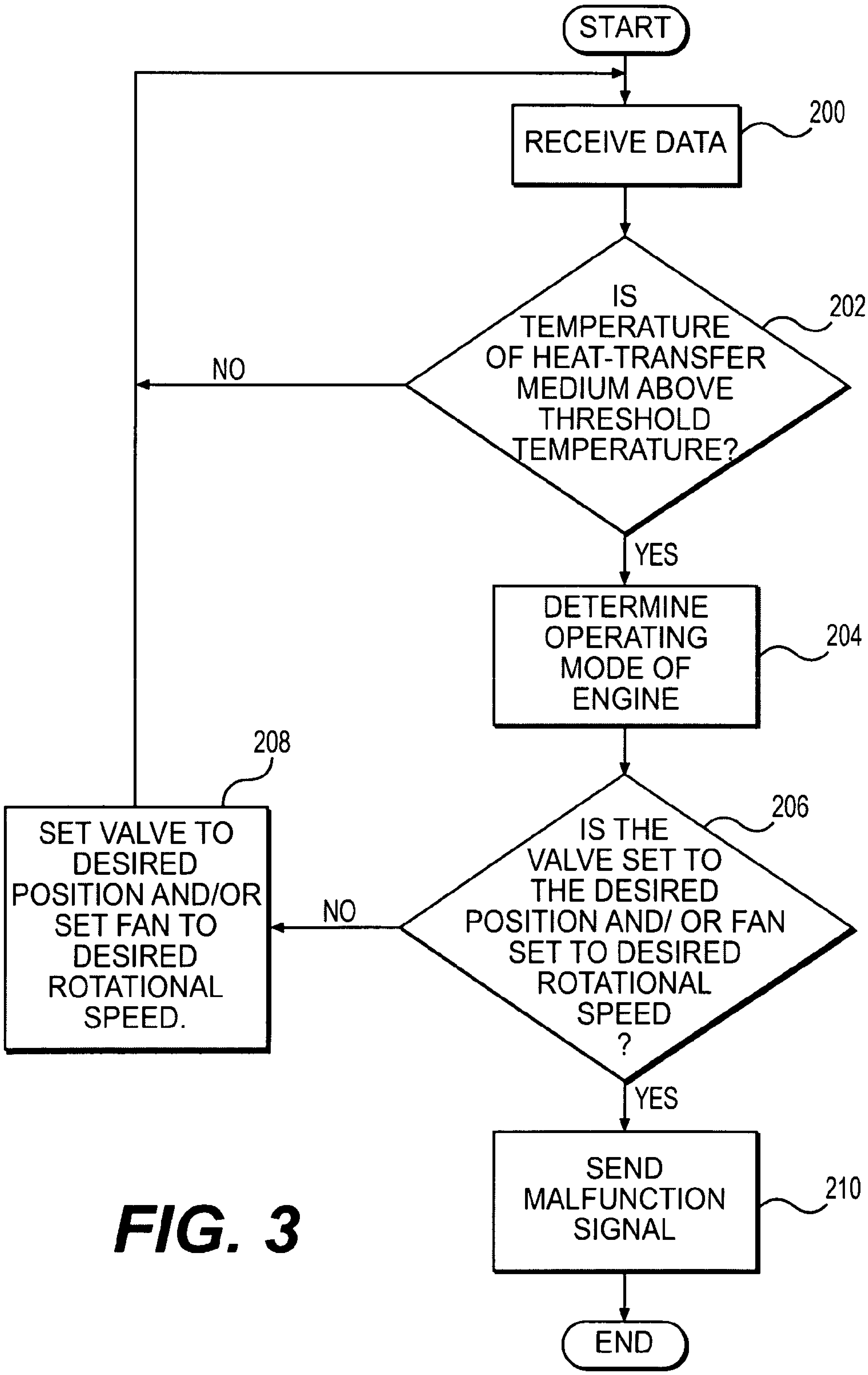

START
RECEIVE DATA
200
IS TEMPERATURE OF HEAT-TRANSFER MEDIUM ABOVE THRESHOLD TEMPERATURE?
202
NO
YES
DETERMINE OPERATING MODE OF ENGINE
204
IS THE VALVE SET TO THE DESIRED POSITION AND/ OR FAN SET TO DESIRED ROTATIONAL SPEED ?
206
NO
SET VALVE TO DESIRED POSITION AND/OR SET FAN TO DESIRED ROTATIONAL SPEED.
208
YES
SEND MALFUNCTION SIGNAL
210
END

FIG. 3

MULTI-STAGE COOLING SYSTEM

TECHNICAL FIELD

The present disclosure is directed to a cooling system and, more particularly, to a multi-stage cooling system.

BACKGROUND

Machines, including track-type tractors, wheel loaders, haul trucks, and other construction and mining equipment, are used for a variety of tasks. In order to accomplish these tasks, the machines typically include an internal combustion engine such as a diesel engine, gasoline engine, or gaseous fuel-powered engine that produces significant amounts of power by combusting a fuel/air mixture. This combustion process generates large amounts of heat. In order to ensure proper and efficient operation of the engine, a cooling system is required to cool fluids directed into or out of the engine.

For example, an internal combustion engine is generally fluidly connected to several different liquid-to-air and/or air-to air heat exchangers to cool both liquids and gases circulated throughout the engine. These heat exchangers are often located close together and/or close to the engine to conserve space on the machine. A fan is disposed either in front of the engine/exchanger package to blow air across the exchangers and the engine, or between the exchangers and engine to suck air past the exchangers and blow air past the engine.

The size of the engine and power output of the engine may be at least partially dependent on the amount of cooling provided to the engine. That is, the engine may have a maximum temperature and a most efficient operating temperature range. Operation of the engine may be limited by the capacity of the associated exchangers to maintain the engine's temperatures below the maximum limit and within the optimum range. In addition, given the space constraints of a particular engine's enclosure, the size of the exchangers may also be limited. Therefore, it becomes necessary to maximize cooling efficiency for a given space constraint.

Maximizing cooling efficiency can be difficult, especially when multiple engine and non-engine heat exchangers are packaged together. That is, in some configurations, air-to-air after coolers (ATAAC) are co-located with engine heat exchangers to take advantage of the airflow generated by the fan. In these situations, the heat transfer from the ATAACs can affect the heat transfer from the engine's exchangers, as well as consume space within the engine's compartment.

One attempt to maximize machine cooling within a given engine compartment is disclosed in U.S. Pat. No. 7,228,885 (the '885 patent), issued to Kolb et al. on Jun. 12, 2007. The '885 patent describes a heat exchanger package for an engine system. The heat exchanger package includes a radiator having upper and lower portions for cooling engine coolant and a charge air cooler having upper and lower portions for cooling charge air. The upper charge air cooler portion is disposed adjacent to and overlapping the upper radiator portion. In addition, the lower charge air cooler portion is disposed adjacent to and overlapping the lower radiator portion. Furthermore, the upper charge air cooler portion and the lower radiator portion are aligned in a first plane, while the upper radiator portion and the lower charger air cooler portion are aligned in a second plane behind the first plane. Ambient cooling air flows in series through the upper charge air cooler portion and the upper radiator portion and in series through the lower charge air cooler portion and the lower radiator portion.

Although the cooling system of the '885 patent may provide a compact heat exchanger package, the efficiency and

cooling capacity may be limited. In particular, the cooling system does not account for the changing relationship between the radiator and charge air heat loads of different engine operating conditions. For example, during some engine operating conditions, the radiator and charge air heat load may increase or decrease together. In other engine operating modes, the radiator and charge air heat loads may increase or decrease independently. Therefore, the '885 cooling system, may be efficient under certain engine operating conditions and inefficient under others.

The disclosed cooling system is directed to overcoming one or more of the problems set forth above.

SUMMARY

In one aspect, the present disclosure is directed to a cooling system. The cooling system includes a first heat exchanger configured to remove heat from at least a portion of a first fluid and a second heat exchanger configured to remove heat from a portion of a second fluid. The second heat exchanger is located downstream of the first heat exchanger relative to the flow of air passing through the first heat exchanger so that a substantial portion of the air passing through the first heat exchanger also passes through the second heat exchanger. The cooling system also includes a valve located to regulate the flow of the second fluid through the second heat exchanger. The cooling system further includes a controller configured to actuate the valve to regulate the flow of the second fluid through the second heat exchanger when the first heat exchanger is removing heat from the first fluid.

In another aspect, the present disclosure is directed to a method of cooling a fluid. The method includes directing at least a portion of a first fluid through a first heat exchanger and directing a portion of a second fluid through a second heat exchanger. In addition, the method includes directing air across the first and second heat exchangers so that both heat exchangers receive the air in series. Furthermore, the method includes sensing a parameter indicative of an operating condition of the first heat exchanger and regulating the flow of the second fluid through the second heat exchanger in response to the operating condition of the first heat exchanger.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagrammatic illustration of an exemplary disclosed machine;

FIG. **2** is a pictorial and schematic illustration of an exemplary disclosed cooling system for use with the machine of FIG. **1**; and

FIG. **3** is a flow diagram of an exemplary method for operating the cooling system of FIG. **2**.

DETAILED DESCRIPTION

FIG. **1** illustrates a machine **10** having an engine **12**. Machine **10** may perform some type of operation associated with an industry such as mining, construction, farming, power generation, or any other industry known in the art. For example, machine **10** may embody a machine such as a dozer, a loader, a backhoe, an excavator, a motor grader, a dump truck, or any other suitable earth moving machine. Machine **10** may alternatively embody a generator set, a pump, or another operation-performing machine.

Engine **12** may include multiple components that cooperate to produce a power output. In particular, engine **12** may include an engine block **14** that defines a plurality of cylinders **16**, a piston **18** slidably disposed within each cylinder **16**, and a cylinder head **20** associated with each cylinder **16**. It is contemplated that engine **12** may include additional or different components such as, for example, a valve mechanism associated with cylinder head **20**, one or more fuel injectors, and other components known in the art. For the purposes of this disclosure, engine **12** is depicted and described as a four-stroke diesel engine. One skilled in the art will recognize, however, that engine **12** may be any other type of internal combustion engine such as, for example, a gasoline or a gaseous fuel-powered engine.

Cylinder **16**, piston **18**, and cylinder head **20** may form a combustion chamber **22**. Although the exemplary engine **12** illustrated in FIG. **1** includes four combustion chambers **22**, it is contemplated that engine **12** may include a greater or lesser number of combustion chambers **22** and that combustion chambers **22** may be disposed in an "in-line" configuration, a "V" configuration, or any other suitable configuration.

As is also shown in FIG. **1**, engine **12** may include a plurality of systems that facilitate production of the power output. In particular, engine **12** may include an air induction system **24**, a cooling system **26**, and a control system **28**. It is contemplated that engine **12** may include additional systems such as, for example, an exhaust system, a fuel system, a lubrication system, a transmission system, and other such engine systems that are known in the art.

Air induction system **24** may introduce charged air into combustion chambers **22** of engine **12**. In addition, air induction system **24** may include a compressor **30** of a turbocharger (not shown) in fluid communication with one or more inlet ports **32** of each cylinder head and a throttle valve **34**. It is contemplated that additional and/or different components may be included within air induction system **24** such as, for example, an air cleaner and other means known in the art for introducing charged air into combustion chambers **22**.

Compressor **30** may receive atmospheric air via an inlet **36** and compress the received air to a predetermined pressure level. In addition, compressor **30** may direct the compressed air to inlet ports **32** via fluid conduits **38**, **40**. Furthermore, compressor **30** may embody a fixed geometry compressor, a variable geometry compressor, or any other type of compressor known in the art. It is contemplated that multiple compressors **30** may alternatively be included within air induction system **24** and disposed in a series or parallel relationship, if desired. In such an embodiment utilizing multiple compressors, fluid conduit **40** may direct pre-charged air from the upstream compressors **30** to the compressor **30** that may be furthest downstream.

Throttle valve **34** may be located within fluid conduit **38** between compressor **30** and inlet ports **32** to control the amount of air delivered to combustion chambers **22**. The location of throttle valve **34** may be any suitable position within fluid conduits **38**, **40** such as, for example, before or after cooling system **26**. In addition, throttle valve **34** may be adjustable from a flow-passing position, resisting a spring bias, toward a flow-restricting position. When in the flow-passing position, air may be directed into engine **12** substantially unrestricted. The term restricted, for the purposes of this disclosure, is to be interpreted as at least partially blocked from fluid flow. It is also contemplated that throttle valve **34**, when in the flow-restricting position, may fully block fluid flow. Throttle valve **34** may include a butterfly valve element, a spool valve element, a shutter valve element, a check valve element, a diaphragm valve element, a gate valve element, a shuttle valve element, a ball valve element, a globe valve element, or any other type of valve element known in the art. In addition, throttle valve **34** may be electrically, hydraulically, or pneumatically actuated. It is contemplated that throttle valve **34** may be omitted, if desired.

As illustrated in FIG. **2**, cooling system **26** may include components that collaborate to cool fluids directed through engine **12**. For example, cooling system **26** may include a fan **42** for generating a flow of air across a plurality of heat exchangers, an air-to-air heat exchanger **44** for cooling the inlet air or charged air from air induction system **24**, and liquid-to-air heat exchangers **46**, **48** for cooling a heat-transferring medium circulated throughout engine **12**. It is contemplated that cooling system **26** may include additional and/or different components such as, for example, an oil cooler, an exhaust cooler, one or more valve mechanisms, one or more flow meters, and other cooling system components known in the art.

Fan **42** may produce a flow of air across air-to-air heat exchanger **44** and liquid-to-air heat exchangers **46**, **48**. In addition, fan **42** may be indirectly driven by engine **12** via an input device (not shown) such as, for example, a belt driven pulley, a hydraulically driven motor, or an electrically powered motor. Alternatively, fan **42** may be driven by a source independent of engine **12** such as, for example, a motor (not shown). Fan **42** may also include fan blades **50** fixedly or adjustably connected thereto. Fan **42** may be powered by engine **12** to cause fan blades **50** to blow air across air-to-air heat exchanger **44** and liquid-to-air heat exchangers **46**, **48**. It is contemplated that in an alternate embodiment, fan **42** may be situated to draw air from engine **12** across air-to air heat exchanger **44** and liquid-to-air heat exchangers **46**, **48**.

Air-to-air heat exchanger **44** may be situated downstream from fan **42** and may be oriented so that a maximum surface area may be exposed to the airflow generated by fan **42**. In addition, air-to-air heat exchanger **44** may facilitate the transfer of heat from at least a portion of inlet air or charged air flowing through air induction system **24**. Furthermore, air-to-air heat exchanger **44** may be fluidly connected to engine **12** via fluid conduits **38**, **40**. Inlet or charged air from air induction system **24** may enter air-to-air heat exchanger **44** through an inlet **52** fluidly connected to fluid conduit **38** and exit air-to-air heat exchanger **44** through an outlet **54** fluidly connected to fluid conduit **40**. It is contemplated that air-to-air heat exchanger **44** may be any type of heat exchanger such as, for example, a tube-fin type heat exchanger, a bar plate type heat exchanger, or any other type of heat exchanger known in the art. Additionally, in embodiments where fan **42** may draw air across air-to air heat exchanger **44**, air-to air heat exchanger **44** may be situated upstream of fan **42**.

Liquid-to-air heat exchanger **46** may facilitate the transfer of heat to or from a portion of a heat-transferring medium circulated throughout engine **12** and may include, for example, a tube-fin type heat exchanger, a bar plate type heat exchanger, or any other type of heat exchanger known in the art. In addition, liquid-to-air heat exchanger **46** may be located downstream of and in series with air-to-air heat exchanger **44** relative to the flow of air generated by fan **42**. Such a configuration may permit at least a substantial portion of air passing through air-to-air heat exchanger **44** to also pass through liquid-to-air heat exchanger **46**. Furthermore, the orientation of liquid-to-air heat exchanger **46** may be substantially the same as the orientation of air-to-air heat exchanger **44**. Additionally, in embodiments where fan **42** may draw air across Liquid-to-air heat exchanger **46**, Liquid-to-air heat exchanger **46** may be situated upstream of fan **42**.

Liquid-to-air heat exchanger **46** may be fluidly connected to engine **12** via a supply conduit **56** and a return conduit **58**. The heat-transferring medium from engine **12** may enter liquid-to-air heat exchanger **46** through an inlet **60** fluidly connected to supply conduit **56** via a passage **62** and exit liquid-to-air heat exchanger **46** through an outlet **64** fluidly connected to return conduit **58** via a passage **66**. Furthermore, a valve **68** may be situated within passage **62** or passage **66** and may regulate the flow of the heat-transferring medium to liquid-to-air heat exchanger **46**. It is contemplated that valve **68** may be a simple on/off valve or a proportional-type valve.

Liquid-to-air heat exchanger **48** may also facilitate the transfer of heat to or from a heat-transferring medium circulated throughout engine **12** and may include, for example, a tube-fin type heat exchanger, a bar plate type heat exchanger, or any other type of heat exchanger known in the art. In addition, liquid-to-air heat exchanger **48** may be located so that at least a substantial portion of the air stream flowing through air-to-air heat exchanger **44** may not pass through liquid-to-air heat exchanger **48** and may not substantially affect liquid-to-air heat exchanger **48** thermally. Furthermore, the orientation of liquid-to-air heat exchanger **48** may be substantially the same as the orientations of air-to-air heat exchanger **44** and liquid-to-air heat exchanger **46**. It is contemplated that although FIG. **2** illustrates liquid-to-air heat exchanger **48** being situated next to and substantially in the same plane as liquid-to-air heat exchanger **46**, liquid-to-air heat exchanger **48** may be situated next to and substantially in the same plane as air-to-air heat exchanger **44**, if desired. Additionally, in embodiments where fan **42** may draw air across Liquid-to-air heat exchanger **48**, Liquid-to-air heat exchanger **48** may be situated upstream of fan **42**.

Liquid-to-air heat exchanger **48** may be fluidly connected to engine **12** via supply conduit **56** and return conduit **58**. The heat-transferring medium from engine **12** may enter liquid-to-air heat exchanger **48** through an inlet **70** fluidly connected to supply conduit **56** via a passage **72**. In addition, the heat-transferring medium may exit liquid-to-air heat exchanger **48** through an outlet **74** fluidly connected to return conduit **58** via a passage **76**.

In one exemplary embodiment, liquid-to-air heat exchangers **46**, **48** may function as the main radiators of engine **12** dedicated to conditioning only the heat-transferring medium supplied to engine block **14** or, alternatively, the engine oil cooler, the transmission oil cooler, the brake oil cooler, or any other cooling component of engine **12**. In addition, the heat-transferring medium may be any type of low-pressure fluid. Exemplary low-pressure fluids may include, for example, water, glycol, a water-glycol mixture, a blended air mixture, a power source fluid such as transmission oil, engine oil, brake oil, or diesel fuel, or any other low-pressure fluid known in the art for transferring heat.

Control system **28** may take any form such as, for example, a computer based system, a microprocessor based system, a microcontroller, or any other suitable control type circuit or system. Control system **28** may be located anywhere within machine **10** and may include various components for running software applications designed to regulate various subsystems of the machine **10**. For example, control system **28** may include a central processing unit (CPU), a random access memory (RAM), input/output (I/O) elements, etc. In addition, control system **28** may include sensors **78**, **80**, **82**, and **84** and a controller **86**.

Control system **28** may regulate the operations of fan **42**, air-to air heat exchanger **44** and liquid-to-air heat exchangers **46**, **48** in response to the temperatures of the air around engine **12**, the air flowing through air-to air heat exchanger **44**, and the heat-transferring medium flowing through liquid-to-air heat exchangers **46**, **48**. Such temperatures may be sensed using any number of methods. For example, the temperatures may be directly sensed using sensors **78**, **80**, and **84**. Alternatively, the temperatures may be indirectly sensed based on various parameters of machine **10**. Such parameters may be compared to various charts, graphs, etc. that may be stored within a memory of controller **86**, and the temperatures of the air around engine **12**, the air flowing through air-to air heat exchanger **44**, and the heat-transferring medium flowing through liquid-to-air heat exchangers **46**, **48** may be calculated.

Sensor **78** may be located anywhere within fluid conduit **38** and may include one or more devices for sensing a parameter indicative of a temperature of the intake or charge air entering air-to-air heat exchanger **44**, which may indicate an operating condition of air-to-air heat exchanger **44**. In addition, sensor **78** may include any type of temperature sensing device known in the art. For example, sensor **78** may include a surface-type temperature sensing device that measures a wall temperature at inlet **52**. Alternately, sensor **78** may include a air-type temperature sensing device that directly measures the temperature of the intake or charge air within inlet **52**. Upon measuring the temperature of the intake or charge air, sensor **78** may generate an inlet air temperature signal and send this signal to controller **86** via a communication line **88**, as is known in the art. This temperature signal may be sent continuously, on a periodic basis, or only when prompted to do so by controller **86**, if desired. Furthermore, it is contemplated that sensor **78** may be located within outlet **54**, if desired.

Sensor **80** may be located anywhere within supply conduit **56** and may include one or more devices for sensing a parameter indicative of a temperature of the heat-transferring medium entering liquid-to-air heat exchangers **46**, **48**. In addition, sensor **80** may include any type of temperature sensing device known in the art. For example, sensor **80** may include a surface-type temperature sensing device that measures a wall temperature of supply conduit **56**. Alternately, sensor **80** may include a liquid-type temperature sensing device that directly measures the temperature of the heat-transferring medium within supply conduit **56**. Upon measuring the temperature of the heat-transferring medium, sensor **80** may generate a heat-transferring medium temperature signal and send this signal to controller **86** via a communication line **90**, as is known in the art. This temperature signal may be sent continuously, on a periodic basis, or only when prompted to do so by controller **82**, if desired. Furthermore, it is contemplated that sensor **80** may be located within return conduit **58**, if desired.

Sensor **82** may be associated with fan **42** to sense a rotational speed thereof and may be in communication with controller **86** via a communication line **92**. In one example, sensor **82** may embody a magnetic pickup type of sensor associated with a magnet embedded within a rotational component of fan **42**. During operation of fan **42**, sensor **82** may sense the rotating magnetic field produced by the magnet and generate a signal corresponding to the rotational speed of fan **42**.

Sensor **84** may be situated anywhere within an engine compartment (not shown) of machine **10** to sense the air around engine **12**. In addition, sensor **84** may include any type of temperature sensing device known in the art. For example, sensor **84** may embody a thermocouple or a thermometer-type sensor. Upon measuring the temperature of the air, sensor **84** may generate an engine air temperature signal and send this signal to controller **86** via a communication line **94**, as is known in the art. This temperature signal may be sent continuously, on a periodic basis, or only when prompted to do so by controller **86**, if desired.

Controller **86** may include one or more microprocessors, a memory, a data storage device, a communication hub, and/or other components known in the art. Controller **86** may receive signals from sensors **78** and **80** and analyze the data to determine whether the temperature of the intake or charge air and/or heat transferring medium is within a desired temperature range by comparing the data to threshold temperatures stored in or accessible by controller **86**. If the temperatures are not within the desired temperature range, controller **86** may compare data received from sensors **78**, **80**, **82**, and **84** to algorithms, equations, subroutines, reference look-up maps or tables and establish an output to influence the operation of fan **42** and/or valve **68**. For example, the rotational speed of fan **42** may be adjusted and/or valve **68** may be set to an open, closed, or intermediate position to regulate the flow of the heat transferring medium. The output may be conveyed hydraulically, pneumatically, or electronically. Alternatively, it is contemplated that controller **86** may receive signals from various sensors (not shown) located throughout air induction system **24**, engine **12**, and/or cooling system **26** instead of sensors **78**, **80**, **82**, and **84**. Such sensors may sense parameters that may be used to calculate the temperature of the intake or charge air entering air-to-air heat exchanger **44** and the heat-transferring medium flowing through supply conduit **56** and determine a course of action.

In an alternate embodiment, controller **86** may actuate fan **42** and/or valve **68** in response to various operating conditions of engine **12** instead of or in conjunction with the temperature of intake or charge air entering air-to-air heat exchanger **44** and/or the temperature of the heat-transferring medium flowing through supply conduit **56**. For example, during an engine retarding operation, air induction system **24** may be less active, and the heat load of air-to-air heat exchanger **44** may be reduced. Therefore, upon determining that an engine retarding operation is being performed, it may be desired to increase the rotational speed of fan **42** and/or actuate valve **68** so that the heat-transferring medium may flow through both liquid-to-air heat exchangers **46** and **48** for maximum heat rejection. However, when air induction system **24** is active, the heat load of air-to-air heat exchanger **44** may be high and may adversely affect the operation of liquid-to-air heat exchanger **46**. Because the heat rejection operation of liquid-to-air heat exchanger **46** may be compromised, the temperature of the heat-transferring medium flowing through supply conduit **56** may exceed a desired temperature. Therefore, upon determining that air induction system **24** may be active, it may be desired to actuate valve **68** to restrict the flow of the heat-transferring medium through liquid-to-air heat exchanger **46**, thereby disabling liquid-to-air heat exchanger **46**. It is contemplated that one exemplary method for determining whether or not air induction system **24** is active may include determining a rotational speed of compressor **30**. In particular, if compressor **30** is rotating above a threshold speed, air induction system **24** may be active. In addition, if compressor **30** is rotating below a threshold speed or not rotating at all, air induction system **24** may be inactive. The speed of compressor **30** may be determined by analyzing signals received from various sensors (not shown) associated with compressor **30**.

It is contemplated that machine **10** may include an exhaust gas recirculation system (not shown), which may utilize an exhaust gas recirculation (EGR) cooler (not shown) for cooling recirculated exhaust gas. The EGR cooler may be any type of heat exchanger such as, for example, an air-to-air heat exchanger or a liquid-to-air heat exchanger. In addition, similar to air-to-air heat exchanger **44**, the EGR cooler may be situated upstream or downstream of liquid-to-air heat exchanger **46**. During various engine operations, the EGR system may be less active, and the heat load of the EGR cooler may be reduced. With the reduced heat load from the EGR cooler, it may be more efficient to operate liquid-to-air heat exchanger **46**. Therefore, upon determining that the EGR system is less active, it may be desired to increase the rotational speed of fan **42** and/or actuate valve **68** so that the heat-transferring medium may flow through both liquid-to-air heat exchangers **46** and **48** for maximum heat rejection. However, when the EGR system is active, the heat load of the EGR cooler may be high and may adversely affect the operation of liquid-to-air heat exchanger **46**. Because the heat rejection operation of liquid-to-air heat exchanger **46** may be compromised, the temperature of the heat-transferring medium flowing through supply conduit **56** may exceed a desired temperature. Therefore, upon determining that the EGR system may be active, it may be desired to actuate valve **68** to restrict the flow of the heat-transferring medium through liquid-to-air heat exchanger **46**, thereby disabling liquid-to-air heat exchanger **46**. It is contemplated that one exemplary method for determining whether or not the EGR system is active may include determining a position of an EGR valve (not shown) that may regulate the flow of exhaust gas through the EGR system.

It is further contemplated that machine **10** may include a hydrostatic fluid system (not shown), which may utilize a hydrostatic fluid cooler (not shown) for cooling a hydrostatic fluid flowing through the hydrostatic system. The hydrostatic fluid cooler may be any type of heat exchanger such as, for example, a liquid-to-air heat exchanger. In addition, similar to air-to-air heat exchanger **44**, the hydrostatic fluid cooler may be situated upstream or downstream of liquid-to-air heat exchanger **46**. During various engine operations, the hydrostatic fluid system may be less active, and the heat load of the hydrostatic fluid cooler may be reduced. With the reduced heat load from the hydrostatic fluid cooler, it may be more efficient to operate liquid-to-air heat exchanger **46**. Therefore, upon determining that the hydrostatic fluid system is less active, it may be desired to increase the rotational speed of fan **42** and/or actuate valve **68** so that the heat-transferring medium may flow through both liquid-to-air heat exchangers **46** and **48** for maximum heat rejection. However, when the hydrostatic fluid system is active, the heat load of the hydrostatic fluid cooler may be high and may adversely affect the operation of liquid-to-air heat exchanger **46**. Because the heat rejection operation of liquid-to-air heat exchanger **46** may be compromised, the temperature of the heat-transferring medium flowing through supply conduit **56** may exceed a desired temperature. Therefore, upon determining that the hydrostatic fluid system may be active, it may be desired to actuate valve **68** to restrict the flow of the heat-transferring medium through liquid-to-air heat exchanger **46**, thereby disabling liquid-to-air heat exchanger **46**. It is contemplated that one exemplary method for determining whether or not the hydrostatic fluid system is active may include determining a fluid flow within the hydrostatic fluid system. Any flows above a predetermined threshold may indicate that the hydrostatic fluid system may be active.

FIG. **3**, which is discussed in the following section, illustrates the operation of cooling system **26**. FIG. **3** illustrates an exemplary method for regulating the flow of fluids through cooling system **26**.

INDUSTRIAL APPLICABILITY

The disclosed cooling system may be used in any machine or power system application where multiple heat exchangers must be closely packaged and efficient heat dissipation is important. In particular, the disclosed cooling system may provide unique exchanger packaging strategy that improves dissipation effectiveness within a confined space. The operation of cooling system **26** will now be described.

FIG. **3** illustrates a flow diagram depicting an exemplary method for regulating the flow of fluid through cooling system **26**. The method may begin when controller **86** receives signals from sensors **78**, **80**, **82**, and **84** (step **200**). The signals may be indicative of a temperature of the intake or charge air flowing through fluid conduit **40**, a temperature of the heat-transferring medium flowing through supply conduit **56**, a rotational speed of fan **42**, and a temperature of the air surrounding engine **12**. Alternatively, it is contemplated that controller **86** may receive signals from various sensors (not shown) located throughout air induction system **24**, engine **12**, and/or cooling system **26** instead of sensors **78**, **80**, **82**, and **84**. Such sensors may sense parameters that may be used to calculate the above-mentioned parameters.

After receiving the data signals, controller **86** may determine if the sensed temperature of the heat-transferring medium is greater than a threshold temperature (step **202**). The threshold temperature may be any value above which, the heat-transferring medium may not adequately cool engine **12** and/or any other system being cooled by the heat-transferring medium. If controller **86** determines that the temperature of the heat-transfer medium is less than the temperature threshold (step **202**: No), step **200** may be repeated (i.e., controller **86** may receive signals from sensors **78**, **80**, **82**, and **84**).

If controller **86** determines that the temperature of the heat-transferring medium is greater than the threshold temperature (step **202**: Yes), controller **86** may determine an operating mode of engine **12** (step **204**). For example, controller **86** may determine whether or not air intake system **24** is active, whether or not engine **12** is performing a retarding operation, or whether or not any other operation is being performed. Such a determination made be made via various sensors located throughout machine **10**. For example, any rotational speed of compressor **30** may indicate that air induction system may be active. In addition, if a speed of engine **12** is above a threshold without receiving fuel from a fuel system, engine **12** may be performing a retarding operation.

After determining the operating mode of engine **12**, controller **86** may determine whether or not valve **68** is set to a desired position and/or fan **42** is rotating at a desired speed (step **206**). The desired position of valve **68** and rotational movement of fan **42** may depend on the temperature of the heat-transferring medium flowing through supply conduit **56**, the operating status of engine **12**, and/or the temperature of air surrounding engine **12**. For example, if air induction system **24** is active, air-to-air heat exchanger **44** may be rejecting heat. Because liquid-to-air heat exchanger **46** may be situated downstream from air-to-air heat exchanger **44**, the heat rejected by air-to-air heat exchanger **44** may adversely affect the heat rejecting capability of liquid-to-air heat exchanger **46**. Therefore, it may be desired to set valve **68** to a position that may direct substantially all of the heat-transferring medium through liquid-to-air heat exchanger **48**. In addition, if air induction system **24** is inactive, air-to-air heat exchanger **44** may be rejecting little or no heat. Therefore, valve **68** may be set to a position that may direct the heat-transferring medium through both liquid-to-air heat exchangers **46**, **48**.

If controller **86** determines that valve **68** is not set to the desired position and/or fan **42** is not set to the desired rotational speed (step **206**: No), controller **86** may set valve **68** to the desired position and/or set fan **42** to the desired rotational speed (step **208**). After setting valve **68** to the desired position and/or setting fan **42** to the desired rotational speed, step **200** may be repeated (i.e., controller **86** may receive signals from sensors **78**, **80**, **82**, and **84**). However, if controller **86** determines that valve **68** is set to the desired position and fan **42** is set to the desired rotational speed (step **206**: Yes), controller **86** may send a malfunction signal to the operator (step **210**). Because valve **68** may be set to the desired position and fan **42** may be set to the desired rotational speed, cooling system **26** may be operating at its maximum heat rejecting capacity. If the temperature of the heat-transferring medium flowing through supply conduit **56** is still above the threshold temperature, cooling system **26** may not be able to handle the current heat load. The malfunction signal may be sent to an operator interface (not shown) such as, for example, a computer monitor, a dashboard control panel, or any other user interface known in the art. It is contemplated that in addition to sending a malfunction signal, controller **86** may shut down engine **12** so to prevent any damage that may occur due to increased temperatures. After sending the malfunction signal and/or shutting down engine **12**, the method may be terminated.

By utilizing a configuration including a first and second heat exchanger situated side-by-side and a third heat exchanger situated upstream of the first heat exchanger, the size of the heat exchanger package may be reduced while the cooling system efficiency may increase. In particular, because the first heat exchanger may be selectively disabled when the third heat exchanger is active, the cooling system may account for engine operating conditions where the radiator and charge air heat loads increase or decrease together as well as engine operating conditions where the radiator and charge air increase or decrease independently.

It will be apparent to those skilled in the art that various modifications and variations can be made in the disclosed system without departing from the scope of the disclosure. Other embodiments will be apparent to those skilled in the art from consideration of the specification disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope being indicated by the following claims and their equivalents.

What is claimed is:

1. A cooling system, comprising:

a first heat exchanger configured to remove heat from at least a portion of a first fluid;

a second heat exchanger configured to remove heat from a first portion of a second fluid, the second heat exchanger being located downstream of the first heat exchanger relative to a flow of air passing through the first heat exchanger so that a substantial portion of the air passing through the first heat exchanger also passes through the second heat exchanger;

a third heat exchanger configured to remove heat from a second portion of the second fluid;

a valve located to regulate the flow of the second fluid through the second heat exchanger and the third heat exchanger; and

a controller configured to actuate the valve to regulate the flow of the second fluid through the second heat exchanger and the third heat exchanger based on operation of the first heat exchanger.

2. The cooling system of claim **1**, wherein the third heat exchanger is positioned relative to the first and second heat exchangers so that at least a substantial portion of the air passing through the first heat exchanger does not pass through the third heat exchanger.

3. The cooling system of claim **1**, wherein the second and third heat exchangers are configured to receive portions of the second fluid from one source.

4. The cooling system of claim **3**, wherein the third heat exchanger is configured to receive portions of the second fluid directed away from the second heat exchanger.

5. The cooling system of claim **4**, wherein the second heat exchanger is configured to receive portions of the second fluid directed away from the third heat exchanger.

6. The cooling system of claim **1**, wherein the first heat exchanger is an air-to-air heat exchanger and the second and third heat exchangers are liquid-to-air heat exchangers.

7. The cooling system of claim **1**, wherein the second heat exchanger and the third heat exchanger are situated in a side-by-side arrangement.

8. A method of cooling a fluid, comprising:
- directing at least a portion of a first fluid through a first heat exchanger;
- directing a first portion of a second fluid through a second heat exchanger;
- directing air across the first and second heat exchangers so that the first and second heat exchangers receive the air in series;
- directing a second portion of the second fluid through a third heat exchanger;
- sensing a parameter indicative of an operating condition of the first heat exchanger; and
- regulating the flow of the portions of the second fluid through the second heat exchanger and the third heat exchanger in response to the operating condition of the first heat exchanger.

9. The method of claim **8**, wherein regulating the flow of the portions of the second fluid includes restricting the flow of the second fluid through the second heat exchanger and the third heat exchanger based on heat removed from the first fluid by the first heat exchanger.

10. The method of claim **9**, wherein the parameter indicative of the operating condition of the first heat exchanger is an operating mode of an associated engine.

11. The method of claim **9**, wherein the parameter indicative of the operating condition of the first heat exchanger is an operating status of an air induction system of an associated engine.

12. The method of claim **9**, wherein restricting the flow of the of the second fluid through the second heat exchanger and the third heat exchanger includes disabling the flow of the second fluid through one of the second heat exchanger and the third heat exchanger based on heat removed from the first fluid by the first heat exchanger.

13. The method of claim **8**, further including directing through the third heat exchanger portions of the second fluid directed away from the second heat exchanger.

14. The method of claim **13**, further including directing through the second heat exchanger portions of the second fluid directed away from the third heat exchanger.

15. A machine, comprising:
- an engine;
- an air induction system; and
- a cooling system, including:
  - a first heat exchanger configured to remove heat from at least a portion of an intake air stream flowing through the air induction system;
  - a second heat exchanger configured to remove heat from a portion of an engine cooling fluid, the second heat exchanger being located downstream of the first heat exchanger relative to the flow of air passing through the first heat exchanger so that a substantial portion of the air passing through the first heat exchanger also passes through the second heat exchanger;
  - a valve located to regulate the flow of the engine cooling fluid through the second heat exchanger; and
  - a controller configured to actuate the valve to direct the flow of the engine cooling fluid away from the second heat exchanger based on the first heat exchanger removing heat from intake air flowing through the air induction system.

16. The machine of claim **15**, further including a third heat exchanger positioned relative to the first and second heat exchangers so that at least a substantial portion of the air passing through the first heat exchanger does not pass through the third heat exchanger.

17. The machine of claim **16**, wherein the third heat exchanger is configured to remove heat from at least a portion of the engine cooling fluid.

18. The machine of claim **17**, wherein the third heat exchanger is configured to receive a portion of the engine cooling fluid directed away from the second heat exchanger.

19. The machine of claim **18**, wherein the second heat exchanger is configured to receive a portion of the engine cooling fluid directed away from the third heat exchanger.

20. The machine of claim **19**, wherein the first heat exchanger is an air-to-air heat exchanger and the second and third heat exchangers are liquid-to-air heat exchangers.

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